sac. It is important, also, that the surgeon who operates should not be in attendance, at the time, on cases of erysipelas or hospital gangrene, so as to avoid all possibility of bringing a morbid poison of any kind in contact with the peritoneum.

ART. IX.—*Relative Accommodation.* By E. G. LORING, M. D., of New York. Read before the American Ophthalmological Society. (With figures.)

IT has been considered for some time past as established, that there is a certain amount of independence between the act of convergence and that of accommodation. From this fact there has been a tendency among modern ophthalmologists to look upon the associated action of the ciliary and recti interni muscles as a combination of two separate forces agreeing to act, as it were, in unison, to produce a given object rather than a simple action, composed of two factors mutually dependent upon each other for the means of producing a common result. To such an extent has this idea of independent action been carried, that the term accommodation is now universally applied to the function performed by the ciliary muscle alone. This custom of ignoring the part which the recti muscles play in the normal act of accommodation evidently had its origin in the experiments instituted by modern observers, in order to disprove the assertion that the accommodation was due to the action of the external muscles on the globe of the eye; as well as to refute the theory, propounded by Porterfield, that there was an absolute connection between the convergence of the optical axes and the amount of focalizing power in the eye itself, or, in other words, that "to every degree of convergence there is a fixed and absolute amount of accommodation."

These experiments developed the fact that the action of the ciliary muscle, on the one hand, might be entirely annulled, by actual paralysis, or that artificially produced by atropia, and yet the act of convergence remain undisturbed, while, on the other hand, it has been shown, in one case[1] at least, that all the external muscles may be paralyzed and yet the range of accommodation remain unimpaired. Admitting that the conclusions drawn from both sets of these experiments are true, still, the fact that one element in an associated muscular action may be either partially or totally suspended, while the other continues to perform its usual duty, does not prove that the two can act independently of each other when neither is subjected to any restriction; especially when such restriction has a pathological or artificial origin. This single objection against the arguments advanced above would be conclusive, if it were unanswerable. The answer to this is, that the independent action of the ciliary and recti interni muscles can be proved to exist, when the action of neither is subject to any restriction whatever, that is to say, when the functions of both are at the same moment physiologically perfect. The best proof of this assertion is the fact that a fine object can be placed at a given distance, consequently at a given convergence, and can then be distinctly seen with both eyes, both through convex and concave glasses; showing that the tension of the ciliary muscle can either be relaxed or increased, while the convergence remains the same.

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[1] Graefe's famous case, Archiv für Ophthal., B. II., Abth. II., § 299.

But, admitting that the convergence *does* remain the same while the "accommodation is modified," it does not follow, as would at first sight appear, that this modification of the ciliary muscle is independent of, or unaccompanied by, a corresponding modification in the recti interni, or, in other words, it does not follow that these muscles do not sympathize in the different degrees of nervous impulse to which the ciliary muscle is subjected. On the contrary, *there is reason to believe that for every degree of nervous influence, or increased tension of the ciliary muscle, there is a corresponding and contemporaneous nervous influence or increased tension for the recti interni, even if the optical axes remain fixed.* In order to prove this statement, the following experiment was adopted:—

Expt. I.—Emmetropic eyes with normal amount of vision and accommodation were selected. Snellen's test type was placed at 20 ft., and a lighted taper was so arranged as to be at the level of the lowest line of letters (xx), and, as nearly as possible, in the same plane. The eyes being fixed upon the letters, the visual axes were practically parallel and the tension on the interni, as well as ciliary muscle, at the minimum. Binocular vision was proved to exist by means of prisms. Concave glasses of progressively increasing strength were then successively tried, till a glass was obtained with which vision began to be indistinct. A concave $\frac{1}{16}$ was found to be the strongest glass through which vision was distinct for both eyes. With this glass binocular vision was also apparently perfect, as there was not a particle of diplopia or spreading of the letters or light. This glass represented, then, the amount of relative accommodation which could be called forth independently of convergence; for, as the axes were parallel, the tension on the interni must be at the minimum. If, now, according to the assumption with which we started, every increased tension of the ciliary muscle is accompanied by a corresponding tension of the interni, this increased tension ought to show itself by increased convergence, which would then be expressed by diplopia. Here there was no diplopia; does the assumption fall to the ground? By no means, for if, under the above conditions, a coloured glass was now placed before one eye, diplopia, followed immediately with homonymous images of the flame, separated laterally twenty-three inches. If, now, the images were allowed, by lessening the tension on the interni, to coalesce, and binocular vision again obtained, the letters and light became at once indistinct, showing that by lessening the tension on the interni, we also lessened that of the ciliary muscle, so that the glasses could no longer be overcome. The same result followed if weaker glasses were employed, only the separation between the images was not so great.

The various trials with the different glasses gave the following results: With $-\frac{1}{16}$ the homonymous images were separated laterally 23 inches; with $-\frac{1}{20}$ 12 inches; with $-\frac{1}{30}$ 3 inches; with $-\frac{1}{36}$ the flames overlapped each other. With any weaker glass actual diplopia did not exist, though with $-\frac{1}{42}$, if a point of light was used instead of the flame, there was a perceptible widening of the point. The reason that there was no diplopia with very weak glasses was evidently because the tension on the ciliary muscle in overcoming the glasses, and consequently that on the interni, was so slight as not to be appreciable with the coarse test employed.

The fact that the distance of separation of the images corresponded to the strength of the glasses used, is very significant, and highly corroborative of the assertion that for every tension of the ciliary muscle there is a corresponding tension of the recti interni.

The explanation of the above phenomena is very simple. In order to overcome the concave glasses, a certain amount of increased tension is required of the ciliary muscle. This latter contracts under nervous influence, and vision becomes distinct. If it be true, now, that all nervous action imparted to the ciliary muscle is also extended to the recti interni, then the nervous impulse which enabled the ciliary muscle to contract so as to overcome the concave glasses, must extend itself to the interni, and an increased tension of these muscles would then be the result, and the equilibrium existing between the interni and externi, which was perfect before such increase took place, would necessarily be destroyed, and there would then be a preponderance of power in favour of the interni proportionate to the increase of tension in the ciliary muscle. If such a preponderance of muscular power did exist, it ought to show itself under the well-known test of the coloured glass and prism. We place the coloured glass before one eye (both eyes being, of course, still armed with the concave glasses), and homonymous images are the result, proving beyond doubt the existing want of equilibrium.

But it may be objected to the above course of reasoning, that when the eyes simply look through the concave glasses, the tension of the ciliary muscle in order to overcome these, and consequently that extended to the interni, is just as great without as with the coloured glass. If this be so, the equilibrium between the recti interni and externi, which was perfect before any attempt was made to overcome the glasses, would be lost the moment such attempt was made, and the eye would have the same tendency to turn in when the coloured glass was not employed as when it was. This is true, the tension on the ciliary muscle and that communicated to the interni, is just as great, and the tendency for the eye to turn in is also just as great, in the one case as in the other, but this tendency is resisted and overcome by a factor which is in full force when the eyes are looking through the concave glasses alone, but which ceases to exist the moment the coloured glass is added. This new factor is the intuitive desire for binocular vision. So long as the images on both retinas are equal in intensity, the desire of each eye to perform its share in the common act of vision is so great that every attempt to destroy this by a change in the direction of the optical axes is at once vigorously opposed. As soon as the increased tension in the ciliary muscle (called forth in order to overcome the glasses) is extended to the interni, the change in the visual axes, which would be the natural result, is counterbalanced by the desire for binocular vision, which, in this case, can only be accomplished by the agency of the recti externi, the natural antagonists of the interni. Thus, the equilibrium of the muscles which would have been destroyed by the increased tension of the interni on the one hand, is reinstated and maintained on the other, by a corresponding increased tension of the externi. But as soon as the image on one retina is reduced by placing the coloured glass before one eye, the instigation towards binocular vision is removed; and as soon as the desire ceases, the necessity for the muscular force, by means of which the desire was fulfilled, also ceases; or, more plainly, the externi cease to act. This destroys the equilibrium between the opposing muscles in favour of the interni, and homonymous images are the result. We have only to remove the coloured glass, or, in other words, restore the power, and with the power the desire, for binocular vision and the homonymous images immediately coalesce—thus proving that when the eyes look through the concave glasses alone, there is the same tension on the interni, and the same tendency for the eye to turn in as when the coloured glass is added, but that this tendency is counteracted solely by the desire for binocular vision.

Precisely the same result followed when the experiment was applied for the near as for the distance.[1]

Hitherto we have occupied ourselves in establishing the fact that certain changes in innervation of the ciliary muscle were followed by corresponding changes in that of the interni. But, in order to determine beyond doubt that these two muscular forces are mutually dependent upon each other, we must, strictly speaking, demonstrate the other side of the proposition, viz., that variations in the tension of the interni are followed by corresponding changes in the condition of the ciliary muscle.

Expt. II.—I have the power of letting the right eye deviate from parallel axes sufficient to overcome a prism of 30°, with the angle outwards. The eyes were, as in the previous experiment, armed with a concave $\frac{1}{16}$th, the strongest glass through which vision remained distinct. If, now, the tension on the interni was relaxed so as to allow the right eye to deviate to its utmost, the type (even 200 in 20 feet), immediately became so indistinct that not a letter could be deciphered. Crossed images, separated about three feet, was the result. If these images were now made to approach each other by gradually increasing the tension on the interni, it was found that though the vision improved *pari passu*, it was not till the primary and secondary images coalesced that the type (20 in 20 feet) became distinct. The strong glasses were now laid aside, and numerous trials made with weaker ones. It was ascertained that if the right eye was allowed to deviate to its utmost from the parallel, $-\frac{1}{80}$ could not be overcome by the left, which still performed the act of vision. If, now, the tension on the right internus was increased, and the deviation thereby lessened, so that the secondary image was separated from the primary two feet instead of three, $-\frac{1}{36}$ could be overcome. If the tension was farther increased, so that the images were only separated one foot, $-\frac{1}{24}$ was overcome. By making the images coalesce, $-\frac{1}{16}$. Thus proving that different degrees of tension of the interni were followed by contemporaneous variations of tension in the ciliary muscle.

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[1] In performing this experiment, a good deal of care and some experience is required, in order not to offer any resistance to the eyes following their natural muscular tendency. All intuitive and instinctive attempts at binocular vision must be suppressed, and the eyes left, as it were, to follow passively their own inclinations.

But it may be urged in opposition to the foregoing arguments that in hypermetropia, where the error of refraction is of such a degree as to require about the same amount of tension of the ciliary muscle, as was used by the emmetropic eye in overcoming the concave glasses, and where, at the same time, there was no strabismus, the conditions are precisely the same as those in the experiment; and that as there is increased tension on the ciliary muscle in order to make vision clear for the distance, there ought also to be increased action of the interni which would then destroy the equilibrium of the external muscles as soon as the desire for binocular vision was removed, and this want of equilibrium would then show itself, just as it did in the experiment by homonymous images. While on the contrary it often happens that the equilibrium of the external muscles of hypermetropic eyes is shown to be perfect, even when such eyes are subjected to the test of the coloured glass. But it must be borne in mind that the conditions though apparently the same are by no means identical. Non-squinting hypermetropic eyes have, by long-continued practice, become so accustomed to meet, and successfully resist, the tendency to turn in under accommodative efforts for parallel rays, that an increased tension on the interni, counterbalanced by an increased tension on the externi, may be considered as the normal condition for such eyes, for distant objects. In other words, though the tension of the external muscles of the globe is greater the equilibrium between them is as perfect as in emmetropic eyes, and we have no more right to expect that the coloured glass will show a preponderance of muscular power in hypermetropia, where none exists, than in emmetropia, where there is perfect harmony between the muscles.

Now, in order to make the conditions which obtain in such hypermetropic eyes parallel with those in the example, we must bring forth an amount of accommodation over and above what the hypermetropic eye has been in the habit of using with parallel axes, or, in other words, bring forth the maximum amount of relative accommodation corresponding to this position of the optical axes. We do this by employing the strongest concave glass which such eyes are capable of overcoming with parallel axes and yet maintain binocular single vision. The additional efforts then made by the ciliary muscle to overcome the glasses, ought to be followed by an increased tension on the interni. This would destroy the equilibrium in favour of these muscles and the preponderance of muscular power, kept in abeyance by the desire for binocular vision, would show itself the moment this latter was removed or even lessened. This is the fact, for as soon as the coloured glass is put up homonymous images follow. Of course here, as in the former case, all intuitive desire towards preserving binocular vision by opposing a counterbalancing muscular force must be completely subdued and the eyes left to follow passively the natural muscular tendency.

That there is a strong tendency for *all* hypermetropic eyes to turn in, is now so well established as to need no comment whatever. The reason why some do not is evidently because the equilibrium between the muscles is maintained by an increased exertion on the part of the externi.

When, however, from the error in the refraction the demand on the ciliary muscle and, as a consequence, the tension on the interni, are so great that the strain can no longer be resisted by the externi, the want of equilibrum then shows itself by homonymous images without the accommodation being incited to increased action by concave glasses. This fact is well illustrated by the following examples:—

CASE I.—Miss A. H., æt. 18, has some of the symptoms of asthenopia from hypermetropia. Letters, however, only occasionally become indistinct, and the pain is rather in the eyeball than over the brow; this pain is moreover constant. The patient has given up all use of the eyes, but finds no relief from rest. Manifest hypermetropia $=\frac{1}{50}$. Vision in both eyes equals 1. Accommodation $=\frac{1}{5}$. The ophthalmoscopic examination shows a slight atrophic crescent round the optic nerve, which is slightly congested, otherwise the fundus appears perfectly normal. There is no insufficiency of the interni recti; on the contrary, there appears to be some weakness of the externi as homonymous images are called forth by placing a coloured glass over either eye without the addition of a vertically displacing prism. At 20 ft. distance these images are made to coalesce by a prism 7°, base outwards. The images retain their distance of separation to whichever side the flame is moved. If the candle is gradually brought towards the eye the distance between the images decreases *pari passu* till these combine at 24 inches from the eye. At 12 inches images produced by the prism and coloured glass are exactly vertical, showing perfect equilibrium between the recti muscles. At 24 inches the images begin to grow homonymous and the distance between them increases till at 20 feet they are separated "about 2 feet." The patient has never seen double, and can only do so with the red glass.

As the patient could not, after a continued trial, relax the accommodation for more than $+\frac{1}{60}$, and as the vision and total range of accommodation were so good, it was thought that idiopathic weakness of the recti externi must be the cause of the asthenopic troubles. As if in corroboration of this opinion, the examination of the muscles showed that the power of abduction at 15 inches was only equal to a prism of 5°. Thorough paralysis of the accommodation, however, revealed total hypermetropia, $\frac{1}{10}$. With these glasses the homonymous images no longer existed.

CASE II.—L. K., æt. 19, suffers from asthenopia, the principal symptom of which is "blurring" while engaged on close work. The patient has no pain in the eye or over the brow, but has suffered much from "general headache." There is no manifest hypermetropia and vision equals $\frac{2}{3}$. Accommodation $= \frac{1}{6}$. The patient sees homonymous images with the coloured glass, without any displacing prism, separated at 20 feet, 18 inches. These images combine when the candle is brought to a distance of 4 feet from the eye. A prism of 7° base outwards reduces the diplopia for the distance. At 6 inches, images produced by a prism, base upwards or downwards, are vertical, from this point outward, homonymous. The patient has never seen double, and can only do so with the aid of the coloured glass. Thorough paralysis of the accommodation shows total hypermetropia $= \frac{1}{8}$. Through this glass the candle is seen distinctly, and the double homonymous images, which were present before the accommodation was paralyzed, have entirely disappeared, and the equilibrium of the muscles is perfect. After the effect of the atropia had passed off $+\frac{1}{18}$ was ordered, as this was the strongest glass which the patient would tolerate. Three weeks later, through $+\frac{1}{14}$ (the coloured glass being placed over one eye), there was no diplopia; but if the spectacles were raised over the brow while the coloured glass still remained before one eye, double homonymous images followed at once, which again immediately disappeared as soon as the glasses were lowered again.

CASE III.—E. W., æt. 45, has all the symptoms of asthenopia from hypermetropia. $Hm = \frac{1}{18}$. $V = 1$. A, normal. With the coloured glass and no spectacles the patient sees homonymous images, separated 10 inches in 20 feet. With $+\frac{1}{18}$ the diplopia ceases, and a vertically displacing prism then gives vertical images. If the spectacles are raised, however, double images follow at once, and it requires a prism of 6° base outwards to make them combine.

CASE IV.—C. J., æt. 15. $Hm = \frac{1}{30}$. $V = 1$. $A = \frac{1}{5}$. The patient sees homonymous images, separated 8 inches in 20 feet. With $+\frac{1}{30}$ double images disappear.

CASE V.—A. T., æt. 10, has all the symptoms of asthenopia from hypermetropia. $Hm = \frac{1}{13}$. $V = 1$. A, limited. The patient sees homonymous images, which combine at 20 feet with a prism of 9°. With the glass which corrects the manifest hypermetropia ($+\frac{1}{13}$) the images approach each other very much, while without it they are widely separated. The accommodation was paralyzed, and the total hypermetropia found to be equal to $\frac{1}{6\frac{1}{2}}$. Through $+\frac{1}{6\frac{1}{2}}$ there was no diplopia.

From the above it would follow that not only are the demands on the ciliary muscle greater for the distance in hypermetropia than in emmetropia, but that there is also an amount of labour imposed both on the interni and externi recti muscles in the case of non-squinting hypermetropic eyes, which does not exist at all in the normal organ; and furthermore, that the amount of this increased taxation on the external muscles is proportionate to the error of refraction, always provided that the attempt is made to neutralize the hypermetropia by accommodative efforts.

But it may be suggested that in the above cases there might have been some idiopathic weakness in the externi, which would have then showed itself, by the test employed, by homonymous images, independently of accommodative efforts. That there was no such weakness, and that the homonymous images were solely due to the act of accommodation, is proved by the fact that the diplopia disappeared the moment the strain on the ciliary muscle was removed by atropia or convex glasses. At the same time, I would not wish to imply that weakness of the externi recti, analogous to that of the interni, might not even occur, for I have myself seen cases of it. That such weakness would more frequently occur in hypermetropia, can be readily understood.

The fact that homonymous images do not appear in all hypermetropic eyes, when subjected to this test, does not prove that the nervous impulse, by which the error of refraction is overcome, is not propagated to the interni. It only proves that the equilibrium is preserved between the muscles, and shows simply that we may increase the tension on the interni indefinitely, provided this is met and counterbalanced by an increased tension on the externi. In other words, the desire for binocular vision and the power to maintain it are so great in some hypermetropic eyes that they are unable, as it were, to give it up even under the greatest pressure of accommodation. But this difference in desire for binocular vision is just as well marked in emmetropia as in hypermetropia, as is shown by the great variations in the amounts of abduction and adduction which perfectly normal eyes often show; some eyes not being able to overcome prisms of very low degree for the sake of preserving binocular vision, while others can overcome those of a very high degree.

While, on the other hand, the fact that with some hypermetropic eyes homonymous images *are* present so long as accommodative efforts are going on, and disappear as soon as these efforts stop, *does* prove that the tension of the ciliary muscle was propagated to the interni, which gave them a balance of power, which balance of power ceases as soon as the action of the ciliary muscle ceases.

Again, given a case of hypermetropia $= \frac{1}{20}$. When the eyes are subjected to the test no homonymous images follow, although accommodation is going on. On the contrary, vertical images are produced by a prism with the angle upwards or downwards. This proves that the equilibrium between the muscles is perfect. But granting the equilibrium be perfect, it does not follow that the action of the ciliary muscle is not imparted to the interni, and that this is not in turn counterbalanced by the externi.

On the contrary, there is reason to believe that this is exactly what does take place; for if the hypermetropia is increased by adding $-\frac{1}{20}$, making $H = \frac{1}{10}$, homonymous images appear. By adding the glass we increased the tension on the ciliary muscle; this was shared in by the interni, whose tension was thereby so much increased, that the externi could not or would not, for the sake of binocular vision, longer resist the strain, though they were able to do it while H equalled only $\frac{1}{20}$. If, in some hypermetropic eyes, in emmetropic eyes made hypermetropic, in hypermetropic made more hypermetropic, we get homonymous images, showing a preponderance in favour of the interni, is it not more rational to think that there is increased action of the interni, counterbalanced by an increased action of the externi in *all* hypermetropic eyes, even for parallel rays, than to believe that the ciliary muscle acts alone without the coöperation of the other muscles for distant accommodation? Again, if the connection between accommodation and convergence is simply an acquired one, would it not be more natural for a hypermetrope to learn to oppose the increased tension on the interni by a corresponding tension on the part of the externi, the latter being the natural antagonists of the former, than to learn to use the ciliary muscle alone for parallel rays, and in coöperation with the other muscles, for all other rays. If hypermetropes can learn to use the ciliary muscle thus independently, why cannot they go a step further and learn to use the ciliary muscle of *each eye* separately, and thus neutralize the discrepancy in refraction, a thing which, as far as modern science knows, has never been accomplished, even in the smallest degree.

From the fact that the amount of accommodation increases with the degree of convergence, it has generally been considered by modern ophthalmologists that the strabismus which occurs in hypermetropia is due to an independent action of the recti interni, for the direct and specific object of giving assistance to the ciliary muscle, and thereby increasing its power. I cannot help thinking that this view of the matter is wrong, and believing that the *initial step* in the strabismus following accommodative efforts in hypermetropia is solely due to the fact that the recti externi have not sufficient force to counterbalance the increased tension imparted to the interni by the same nervous impulse which enables the ciliary muscle to overcome the error in refraction. While, on the other hand, whenever the power of the externi is sufficient to resist successfully the increased action of the interni, while accommodative efforts are going on, there will then be no strabismus, however great the error in refraction may be. How else do we explain the fact, that of two persons, each of whom has the same amount of vision, the same degree of hypermetropia, and exactly the same range of accommodation, one will squint, and the other not? As the range of accommodation and acuity of vision are the same in the two cases, the eyes of both must be equally strong; and as the error of refraction is the same, the same amount of strength must be expended by each in overcoming the anatomical deficiency, and yet there is strabismus in the one case and not in the other.

It would appear also more rational that that peculiar form of strabismus known as intermitting, which only makes itself apparent in a condition of general debility, should be referred rather to want of power in the externi, than to a direct increase of it in the interni. The occupation of the patient, and the optical condition of the eye being the same in a state of temporary weakness as in a state of health, there will be the same motive and the same necessity for accurate accommodation in the one case as in the other; while, on the other hand, the desire for binocular vision decreases with the obstacles placed in its way, and as this was barely maintained by the exertions of the externi while in full vigor; and as, too, there is no absolute necessity for binocular vision as there is for accurate accommodation, imperfect and perhaps painful vision with the two eyes is willingly discarded for distinct and easy vision with one.

Very much more might be said in relation to this interesting point, but it would be beyond the scope of the present remarks.

Hitherto parallel visual axes have been selected as a basis for the experiments used, and the conclusions deduced from them, as in this position of the eyes the tension on the recti interni and ciliary muscles must be at the minimum.

The following experiments and accompanying remarks relate to the action of the recti and ciliary muscles under a convergence of the optical axes. Modern ophthalmologists have denied the old idea that the connection between convergence and accommodation is absolute, so that to every degree of the former there is a fixed amount of the latter. It is now considered settled beyond a doubt that a certain independence exists between these two muscular forces; and for the proof of this independence two assertions, alleged to be indisputable, are brought forward :—

1. That the accommodation may be altered, and yet the convergence remain the same.

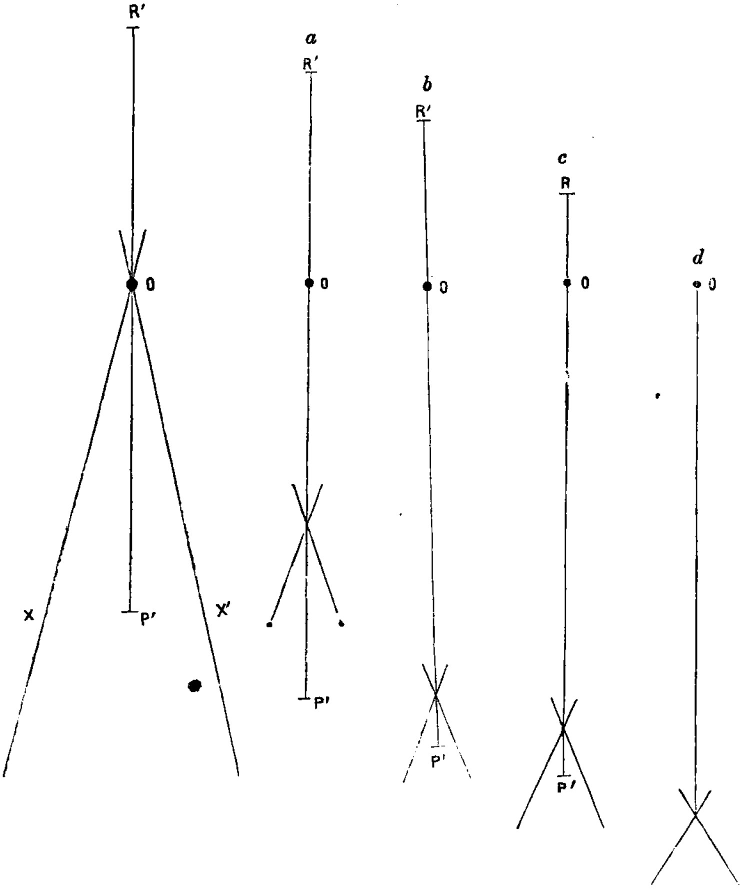
2. That the direction of the optical axes may be changed without modifying the accommodation.

As the whole idea and very existence of relative accommodation depend on the correctness of the above statements, we propose to examine them somewhat in detail.

The first question which naturally presents itself is, whether the assertion that the "accommodation can be modified while the convergence remains the same," be true?

The best argument in its favour, and one which has been universally accepted as conclusive, is that contained in the experiments made by Donders with convex and concave glasses, by means of which he established the amount of accommodation for the different degrees of convergence, from parallel visual lines to a distance of about two inches from the eye. As the admirable diagram, with which he illustrated his experiments, is more elaborate than is necessary for the present purpose, the same principle has been applied to a single degree of convergence. In this diagram (Fig. 1) the eyes are supposed to be converged upon an object at 18 inches from the eye. The visual axes are represented by x and x'; the object viewed consisting of small type, is situated at their point of intersection, and is denoted by o, which, as the accommodation is adjusted for that distance, is seen with distinctness. Now, the strongest convex glass through which the object o still remains distinct, shows the amount that the ciliary muscle can be relaxed at this definite degree of convergence, and is represented on the vertical line as extending from o to r'. This is known as the negative portion of the relative accommodation, and in this case was equal to a convex $\frac{1}{20}$. On the other hand, the strongest con-

Fig. 1.



cave glass, through which *o* still remained distinct, shows the amount of accommodation which can be brought forth by increased tension or muscular effort, and is represented by the distance from *o* to p'. This is called the positive part, and in this case equalled a concave $\frac{1}{14}$. The sum of the two, $\frac{1}{14}+\frac{1}{20}=\frac{1}{8\frac{1}{4}}$, represents the amount of variation of which the accommodation is capable, with this fixed and invariable degree of convergence.

From this it is plain, that no doubt can exist about the actual variations in tension of the ciliary muscle under the influence of the glasses; the only question which can possibly arise is, whether such modification is not accompanied by a change in the position of the visual lines? Here, too, it must be admitted as actually proved, that there is no change in the optical axes, even when the ciliary muscle is compelled by the glasses to pass from its maximum state of relaxation to that of its maximum tension. We are, then, compelled to accept as true the assertion that "the accommodation may be modified, while the convergence remains the same."

This brings us to the second, and, as it were, correlative assertion, brought forward in support of relative accommodation, viz., that the convergence can be altered, and yet the accommodation remain unmodified. Here, too, the best proof of this statement is that furnished by the simple experiments made by Donders with prisms, by the use of which, to use his own words, "we easily convince ourselves that an object can be accurately seen with both eyes at the same distance, and that, consequently, the convergence may be altered without modifying the accommodation."[1]

There can be no doubt whatever in regard to the truth of the statement that an object can be distinctly seen with both eyes at the same distance through prisms of various strengths, whether the angles be turned inwards or outwards, and, consequently, under different degrees of convergence. But, does the fact that the object *can* be so seen, prove that the convergence may be altered without "*modifying* the accommodation?" We think not; and it is to prove that this last statement is incorrect that the following experiments were made.

Precisely the same conditions as those represented in Fig. 1, were taken. Here it will be remembered that the strongest convex glass through which *o* remained distinct was + $\frac{1}{20}$, and its value was represented on the vertical line as extending from *o* to r'. On the other hand the strongest concave glass was —$\frac{1}{14}$, and was represented as extending from *o* to p'. If now, as Donders affirms, the convergence may be altered without *modifying* the accommodation, then we may change the direction of the visual axes, and yet the object will still be distinctly seen through the same glasses both convex and concave, as these are in fact but the representations of the accommodation. In other words, we may alter the direction of x, r' and x', and yet the points r' and p' will remain the same. We change x and x' by placing a prism, of say 5°, angle inwards, before each eye, which increases the convergence from 18 inches to about 12, while the object still remains perfectly distinct. If now we have not modified the accommodation, we ought on the one hand to be able to allow it to relax for $+\frac{1}{20}$, and on the other hand, be able to overcome a concave $\frac{1}{14}$. But we find on trial that the object appears indistinct through $+\frac{1}{20}$, the strongest glass for which the accommodation can be relaxed being $+\frac{1}{24}$. While on the other hand we find that we cannot only overcome a $-\frac{1}{14\frac{1}{2}}$ but even a $-\frac{1}{11}$, so that the amount of relative accommodation with the prisms is equal to nearly $\frac{1}{7}$ instead of, as in the former case, $\frac{1}{8\frac{1}{2}}$.

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[1] Accommodation and Refraction of the Eye, p. 111.

The various changes which have followed the alteration of the convergence by the prisms are represented in Fig. 1, diagram *a*. The optical axes x and x' intersect each other nearer the eye. r' the relative far point, and p' the relative near point, descending on the vertical line, have approached the eye, while o being a fixed object has remained stationary, and it will be seen that o, instead of lying at the point of intersection of the optical axes, and just at the line of division between the positive and negative parts of the relative accommodation, now lies in the upper half of the negative. By increasing the convergence we have not only displaced the relative accommodation but also increased it; while at the same time we have changed the proportion between the positive and negative, so that the latter predominates over the former, which is just the reverse of what it was before the convergence was increased. All these changes in the condition of the relative accommodation are exactly similar in kind, and very nearly identical in degree with those which would have followed had the eyes been converged to 12 inches, naturally, instead of by means of prisms.

If, now, instead of prisms the united angles of which amount to 10° we use those which amount to 20°, we see exactly the same changes taking place, differing only in degree. Fig. 1, diagram *b*, Here $+\frac{1}{30}$ is the strongest convex glass through which the object remains distinct, while on the other hand $-\frac{1}{10}$ can be overcome, making the entire relative accommodation equal to $\frac{1}{7}$.

In diagram *c*, where the united angles of the prisms equal 25°, the convex glass is $\frac{1}{50}$, and the concave $\frac{1}{9\frac{1}{2}}$, the entire relative A being $\frac{1}{8}$.

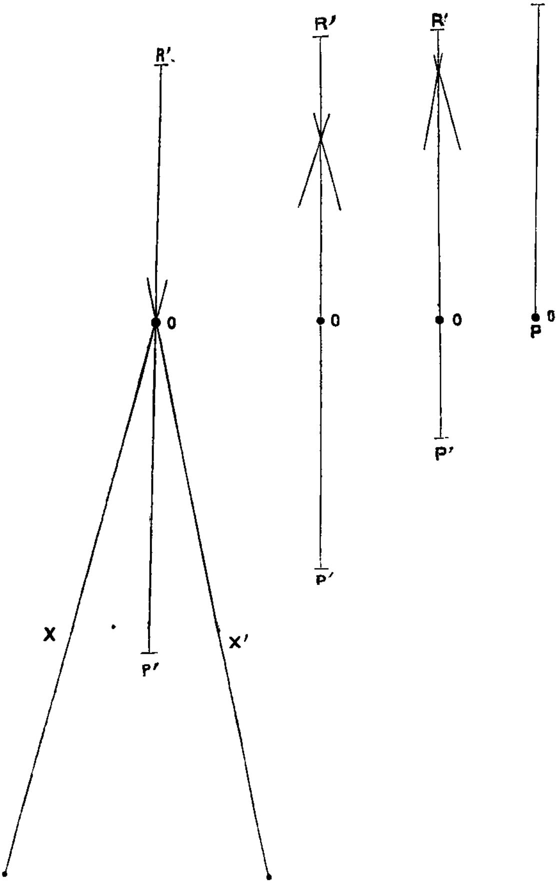
In diagram D, where the united angles of the prisms equal 30°, the accommodation could not be relaxed even for so weak a glass as $+\frac{1}{80}$, as was shown by the fact that vision was made indistinct by it.

It will be seen that the positive part of the relative accommodation has become successively smaller through the series of diagrams from A to D, in which it has no existence at all, the relative A being consequently all negative. And it will be observed, too, that whereas the object *o*, in Fig. 1, *a*, lay at the very beginning of the negative portion, in *d* it lies at its furthest extremity.

If, now, instead of increasing the convergence by turning the angle of the prisms inwards, we lessen it by placing the angle outwards, a result identical in kind follows, only the optical axes intersect further from the eye, and the relative accommodation is likewise removed and the proportions between its negative and positive portions modified.

Fig. 2 represents the various changes produced by the prisms, the angles being here placed outwards. Weaker prisms are employed in this case as the optical axes are rendered parallel by prisms, the united angles of which amount to 15°, consequently those were used whose united angles amounted to 5°, 10°, and 15°, instead of as in the former case, 10, 20, 30.

Fig. 2.



It will be seen that just as *o* was, in Fig. 1, always within the negative portion of the relative accommodation, so here (Fig. 2) it is always within the positive, and just as *r′* in Fig. 1, with increased convergence it gradually descends to *o*, so in Fig. 2, *p′*, under diminished convergence, it ascends to *o*.

The weakest glass through which any appreciable effect was obtained was $2\frac{1}{2}°$ over each eye, but this effect was too slight to be represented in a diagram on so small a scale in Fig. 1. Moreover, in this case, a minute point of light was used instead of small type.

Now it is very true that the object "has been distinctly seen at the same distance with all these different degrees of convergence," but it is not true that the accommodation has not been modified; for, with every alteration in the convergence, there has been a palpable and computable modification of the accommodation, equalling, in the aggregate, to a convex glass of $\frac{1}{8\frac{1}{4}}$.

The reason why the object *o* remains distinct while the convergence is changed by the prisms, is, then, not because the accommodation has not been modified, but because the object remains within the limits of such modification, or, in other words, within the *region* of the relative accommodation, notwithstanding the alteration in convergence.

From Fig. 1 it becomes evident that the convergence may be increased at pleasure, and yet the object will be distinctly seen so long as it remains in the region represented by the negative portion of the relative accommodation, that is, till *r′* descends to *o;* while, on the other hand, Fig. 2 shows that the convergence may be diminished till *p′* ascends to *o*. When, however, in either case, *o* remains outside of the limits of the relative A, it at once becomes indistinct.

From the above experiments it would appear to have been satisfactorily demonstrated that the statements made by Donders, in regard to relative accommodation, are in part correct and in part incorrect; for it is true, as Donders asserts on the one hand, that without change of convergence the accommodation may be modified, but it is not true, on the other hand, that the convergence may be altered without modifying the accommodation; or at least his experiments do not prove it.

It certainly seems strange, and even contradictory, at first sight, that the action of the ciliary muscle, even when excited to a considerable degree, should not affect the convergence, while even a slight change in the optical axes does affect the ciliary muscle. But it must be borne in mind that the conditions in the two cases are very different. The intimate connection between the action of the ciliary muscle and the recti interni has been shown in the preceding part of this paper, and formulated in the proposition that "to every increased action of the ciliary muscle there is a corresponding increased tension of the interni;" and it was fully explained that the only reason why the convergence remained unaltered while the ciliary muscle was incited to increased tension by means of concave glasses, was because the increased tension imparted to the interni, which would turn the eyes, was counterbalanced by the antagonistic muscular contraction of the externi, incited by the intuitive desire for binocular vision. The result of which is that the ciliary muscle has a certain freedom of play or range of action, independent of any change in the optical axes. But, on the other hand, the ciliary muscle, having no antagonist, and there being no intuitive desire to call forth the action of such antagonist did it exist, naturally assumes with the different variations in the optical axes, under the action of the prisms, that amount of tension which it has been accustomed to associate with a given degree of convergence; so that when this latter is changed, even in a trifling degree, a corresponding change takes place in the tension of the ciliary muscle, altering at once the amount and character of the relative accommodation.

In conclusion, it would appear to have been satisfactorily proved that in emmetropia, with parallel axes, when there is at least action of the ciliary muscle, there is also the minimum amount of tension on the interni; (2) That for every increased tension on the ciliary muscle, there is a corresponding tension on the interni, and *vice versa;* and that this increase, as far as relative accommodation is concerned, is counterbalanced by an opposing muscular force in the recti externi, which maintains the direction of the visual axes.

From this it would appear to follow that the old idea that a definite convergence is attended with a definite amount of accommodation, is, *physiologically* speaking, the more correct one, since relative accommodation is only the result of an artificial stimulus to which the natural eye is never subjected. And further, it is not, as has been asserted, the expression of the force of the ciliary muscle, but of a set of muscles, consisting of the ciliary, recti interni and externi muscles, and perhaps others of the extra ocular group.

The above applies, of course, only to normal emmetropic eyes.

It remains to be added, in this connection, that the belief, which has existed for some time, that the ciliary muscles of a pair of normal eyes cannot act independently of each other, has been rather strengthened than refuted by more modern observers (Graefe,[1] Donders,[2] Hering[3]).

Their experiments go to prove that the accommodation cannot be varied in one eye without being varied in the same degree in the other. This holds good, as well for the associated movements of the eye as for direct convergence of the visual axes; for the reason that the *sum* of nervous force expended by the interni during the associated movements, where one internus is elongated and the other forcibly contracted, is as great as it is where, in direct convergence, each muscle is equally contracted.

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[1] Archiv, Ophth. B. 8, ab. II., 1862, p. 331.

[2] Zehender Klin. Monatsblät., June, 1866, p. 173.

[3] Die Lehre vom Binoc Sehen, 1866, p. 136.

These principles, advanced by the earlier writers, have been lately discussed in their fullest detail by Prof. Hering, with what appears a claim for originality. We cannot, however, see any important distinction between saying, as has been done repeatedly, that the two ciliary muscles cannot act independently, and saying that the two eyes, as far as the ciliary muscle is concerned, must be looked upon as a "single eye." (Binoc Sehen, p. 136).

ART. X.—*Venesection as one of the Means for the Arrest of Unavoidable Hemorrhage.* By C. C. F. GAY, M. D., Member of the Surgical Staff of the Buffalo General Hospital, Buffalo, N. Y.

NOTWITHSTANDING the laborious researches of the best medical thinkers of this and of the old world, it is claimed by many that no progress has been made during the last three decades in our knowledge of the means for averting fatal results from hemorrhage in placenta prævia. Although less has been accomplished than could be desired, the profession have a right to denounce as libellous this statement. Achievements in this department of our science, for obvious reasons, have been tardy of accomplishment, since it falls within the province of few medical men in general practice to treat more than a case or two of central implantation during their entire professional career. Many may have passed a lifetime without seeing a case, hence it is to those more favoured brethren who occupy public positions, that the general practitioner must look for light obtained from their more extended field of clinical observations. An observer, however limited may have been his opportunities, cannot be excused for withholding from the profession any theory, fact, or experience, of which he may be cognizant, however insignificant his own personal observatious may appear to himself.

Pervaded by a sense of duty to others, and a desire to contribute something to our present knowledge, I assume the task of giving to the medical public the results of my own personal observations, based upon the management of five cases of unavoidable hemorrhage, four of which I saw in consultation, and one occurred in my own private practice. Three of them were cases of placenta prævia centralis, and two cases of placenta lateralis.

As an illustration of the tardiness of men to accept newly-discovered truths, to indorse medical innovations, and of the slow and deliberate strides by which the science of medicine has made its way to public esteem, I may state that it was not until the latter part of the seventeenth century the discovery was made that the placenta, in placental presentations, was